ASTER Validation Plan Summary Charts

Version 1.03
(October 15, 1998)

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1.0 Introduction

This document summarizes the validation plans for the ASTER standard data products. The document follows the outline recommend by Dr Starr in his letter dated July 31st 1996 to the ASTER Science Team Leader. Initially the data products are listed and the relevant instrument characteristics. This is followed by the validation plan summaries for each product. The interdependencies of the various data products are given in Figure 1.

2.0 Standard Data Products

Registered radiance at sensor (AST03)
Decorrelation stretch (AST06)
Brightness temperature (AST04)
Surface radiance - VNIR, SWIR (AST09)
Surface reflectance - VNIR, SWIR (AST07)
Surface radiance - TIR (AST09)
Surface kinetic temperature (AST08)
Surface emissivity (AST05)
Polar surface and cloud classification (AST13)
Digital Elevation Model (AST14)

3.0 Relevant Instrument Characteristics

The EOS AM platform, scheduled for launch in 1998, will be placed in a 10:30 a.m. descending, sun-synchronous, polar orbit at an altitude 705 km. The ASTER instrument is designed for a 6-year lifetime. It consists of three bore-sighted sub-systems for the visible and near infra-red (VNIR), short wave infra-red (SWIR) and the thermal infra-red (TIR) respectively. ASTER has 14 spectral bands covering the range 0.56 to 11.3 μm, 3 spectral bands in the VNIR, 6 in the SWIR, and 5 in the TIR.

VNIR:

- 15 m spatial resolution
- Pointing capability of ±24 degrees
- 3 spectral bands for nadir viewing between 0.52 and 0.86 μm
- 1 spectral band for backward viewing with a B/H ratio of 0.6
- 60 km swath width
- NEΔR of 0.5 % or better
- an absolute accuracy of 4 % or better
- MTF of 0.25 for cross track and 0.2 for along track or better
- 8-bit digitization.
- On-board calibration:
    1) Two independent, narrow-beam systems, except for the uncalibrated stereo camera
    2) Tungsten lamp sources

3) Each lamp and each output monitored by a photodiode
4) Calibration every 17 days

SWIR:

30 m spatial resolution
Pointing capability of ±8.55 degrees
6 spectral bands between 1.60 and 2.43 µm
60 km swath width
NEΔR of 0.5 - 1.3 % or better depending on bands
Absolute accuracy of 4 % or better
MTF of 0.25 for cross track and 0.2 for along track or better
8-bit digitization
On-board calibration:

1) Single beam of radiation from tungsten source
2) No intervening optics except pointing mirror
3) Tungsten lamp monitored by photodetector
4) Calibration every 17 days

TIR:

a spatial resolution of 90 meters
a pointing capability of ±8.55 degrees
5 spectral bands between 8.125 and 11.65 µm
a swath width of 60 km
a NEdT of 0.3 K or better
an absolute accuracy of 1 - 3 K depending on bands
a MTF of 0.25 for cross track and 0.2 for along track or better
12-bit digitization
On-board calibration:

1) Blackbody source used in range 270 to 340 K
2) Long-term calibration every 17 days
3) Short-term calibration at 270 K before and after each image
4) Temperature scales from 270 - 200 K and 340 - 370 K by extrapolation

Channel Specifications

Subsystem (& detectors)	Band no.	Filter wavelengths for 0.5 of max transmittance (µm)	Radiometric resolution	Signal quantization (bits)	Uncertainty in absolute calibration, one sigma
VNIR (Si-CCD, 5000 4)	1 2 3	0.52 - 0.60 0.63 - 0.69 0.76 - 0.86	0.5% applies to all bands	8 applies to all bands	±4% applies to all bands
SWIR (Cooled Pt Si	4 5 6 7	1.600 - 1.700 2.145 - 2.185 2.185 - 2.225 2.235 - 2.285	0.5% 1.3% 1.3% 1.3%	8 applies to all bands	±4% applies to all bands

2048 _ 6)	8 9	2.295 - 2.365 2.360 - 2.430	1.0% 1.3%		
TIR (Cooled HgCdTe PC 10 _ 5)	10 11 12 13 14	8.125 - 8.475 8.475 - 8.825 8.925 - 9.275 10.25 - 10.95 10.95 - 11.65	2.5 K* 2.5 K* 2.5 K* 1.5 K* 1.5 K*	12 applies to all bands	3 K (200 - 240 K) 2 K (240 - 270 K) 1 K (270 - 340 K) 2 K (340 - 370 K) applies to all bands

***** These values are for low-level input radiances. For high-level input radiances, 0.3 K applies to all bands.

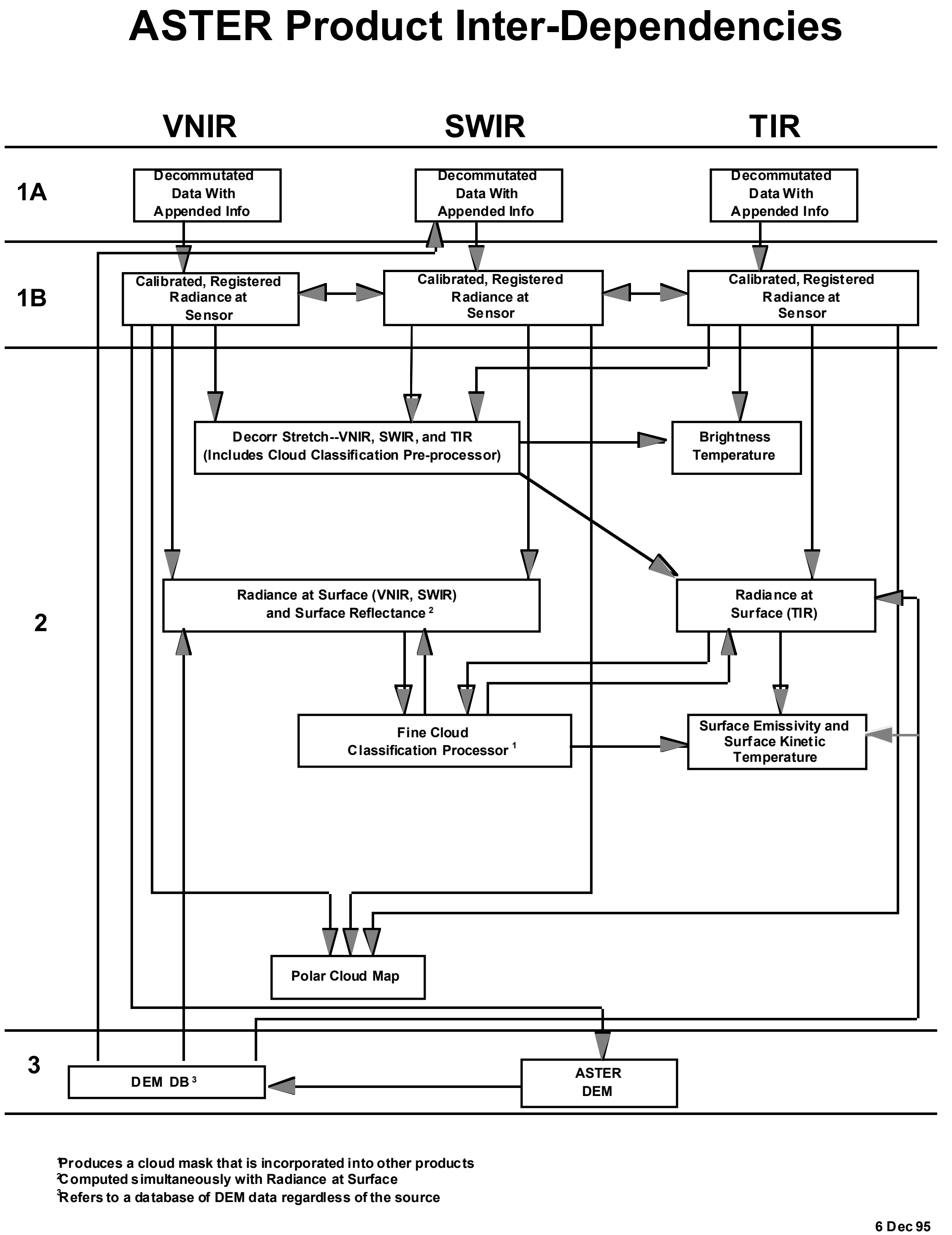

Figure 1. ASTER Product interdependencies

4.0 Registered Radiance at Sensor (AST03)

TOA radiances are produced by applying the ASTER calibration coefficients to the digital counts obtained from the image of a given site. Calibration coefficients are derived from the ASTER Level-1B algorithm using data from the on-board calibrators (OBCs) as input. The anticipated absolute calibration for the ASTER channels is given in section 3.0 on Relevant Instrument Parameters. The absolute calibration of ASTER will be validated by vicarious calibration, which involves using the comparison of ASTER radiances to calibrated sources external to ASTER. These include:

a) Reflectance calibrated sites
b) Radiance calibrated sites, including the moon
c) Temperature/emissivity calibrated sites
d) Measurements at the surface or aboard aircraft simultaneous with ASTER imaging
e) Cross comparisons made with other sensors

For all of the above cases the highest accuracy is obtained by using large areas of uniformly high radiance. The following table lists the different vicarious calibration methodologies and instrumentation.

Parameter	Instrumentation
Radiance Surface TOA	 Aircraft -mounted or surface-traversed radiometers Predicted from RTCs using inputs below
Surface properties $\rho(\lambda)$ BRDF(λ) $\varepsilon(\lambda)$ Temperature	 Aircraft, buoy & surface radiometers. Reflectance panels BRDF radiometers and camera μFTIR, blackbody sources, TIR filter radiometers Thermocouples in buoys, μFTIR, TIR filter radiometers
Atmospheric properties[1] OD(λ) Aerosol & O_3 OD Aerosol size distn. Ängstrom coef. H_2O- vapor OD Phase function Aerosol complex index	 Solar radiometers As above As above As above As above Aureole camera (will not be ready until late 1999) Diffuse/global irradiance, almucantar scans
General Rayleigh OD Line-of-sight monitor Total irradiance down Pressure, temp, R.H.	 Barometric pressure -- meteorological station Narrow-field, pointable, radiometer Pyranometer, all-sky camera Meteorological station, radiosonde

[1] OD stands for optical depth. Some of instrumentation is under development.

4.1 Approach for Establishing Scientific Validity

Five steps are planned to establish validity. These are:

Preflight calibration validation
In-flight VC, and AM-1 sensor cross comparisons
OBC validation during the operational phase
Non-AM-1 sensor cross comparisons
Comparisons with calibration-sensitive Level-2 products

The preflight calibration validation will involve laboratory cross comparisons of the VNIR/SWIR calibration sources used by ASTER, MISR, MODIS. This laboratory work will include laboratory cross-comparison radiometers supplied by GSFC, NIST, NRLM, and the Univ. of Arizona. We will also use joint field campaigns to compare predicted TOA radiances. These campaigns will include representatives from ASTER (Japanese Science Team members from Saga Univ., Ibaraki Univ., and the GSJ, and US Science Team members from JPL and the Univ. of Arizona), MISR, MODIS (Univ. of Arizona), and other groups.

The in-flight vicarious and AM-1 sensor comparisons will involve
1) VCs at various sites during intensive A&E phase
2) Adoption of a variety of locations in order to obtain the maximum number of nadir (<5 degrees) and near-nadir (<30 degrees) opportunities and also surfaces of different reflectances to optimize calibrations in different bands.
3) Initial AM-1 sensor cross comparisons (CCs) simultaneous with VC campaigns, follow-on CCs do not require detailed ground-site characterizations.
4) Night overpasses for TIR VC and AM-1 cross comparisons.

The on-board validation during the operational phase will involve:
1) Periodic VC campaigns at various sites depending on success of previous campaign(s) and ASTER stability with two calibrations each campaign at two-month intervals and one intensive campaign each year
2) AM-1 sensor cross comparisons, usually concurrent with VC campaigns
3) Lunar VC
4) VC via UA sensors and other aircraft-mounted radiometers e.g. AIR-MISR, MAS, AVIRIS, MASTER HAUCSS, TIMS

Lastly, the scientific validity of the OBC will involve comparison with highly calibration-sensitive Level-2 data products such as surface temperature and reflectance/radiance retrieval.

4.2 How will Accuracy, Precision, and Resolution be confirmed?

4.2.1 Radiometric Performance

At an initial stage of the preflight activity performances of gain, offset, non-linearity, stray light and bright target recovery are measured for PFM. Such performances have temperature dependence so that temperature dependence is also being measured and characterized. These measured data are converted to radiometric correction coefficients and temperature coefficients which are contents of the radiometric correction data base files for the Level-1 data processing.

During the preflight calibration and characterization of the EOS-AM1 instruments, there will be a cross-calibration activity to compare the absolute radiometric calibrations of ASTER, MISR, MODIS and MOPITT. This activity will involve the use of several ultra-stable transfer radiometers that will be used to compare the integrating sphere sources and blackbodies (where applicable) used to calibrate these instruments. The transfer radiometers will be provided and operated by personnel from GSFC/NIST, NRLM and University of Arizona. The cross-calibrations will be conducted in ambient for bands in the solar-reflective range and in vacuum for the thermal infrared. The measurements are to be conducted immediately before or after the final preflight calibrations of the ASTER.

The results of these cross-calibrations will be analyzed to determine the magnitude of any systematic differences between the absolute calibrations of the preflight calibration source. Any such differences may be used to modify the preflight calibration coefficients of the instrument.

The initial in-flight calibration will be carried out during the three-month activation and elevation phase. Using the earth images at night for the offset signal and the on-board lamp calibration data, the first in-flight radiometric calibration coefficients will be obtained and compared to the preflight data. In the initial checkout period the vicarious calibration and the cross-calibration with MODIS are also planned to confirm the radiometric accuracy. The details are TBD.

The radiometric calibration activity during the normal operation period will be carried out mainly using a pair of halogen lamps for VNIR and SWIR and a blackbody for TIR. The initial radiometric correction coefficients may be updated every 17 days by new on-board calibration data, if necessary.

The vicarious calibration and the cross-calibration are also planned to confirm the radiometric accuracy. The accuracy of these results will be evaluatd using peer review of uncertainty estimates. We will also rely on the results from the multiple VC paths of the reflectance-based for solar-reflective bands, radiance-based for all bands, and temperature/emissivity for TIR bands to evaluate the accuracy of the combined results.

Joint field campaigns to compare TOA radiances and cross-calibration to other AM-1 sensors will also be used to evaluate the accuracy of the VC results.

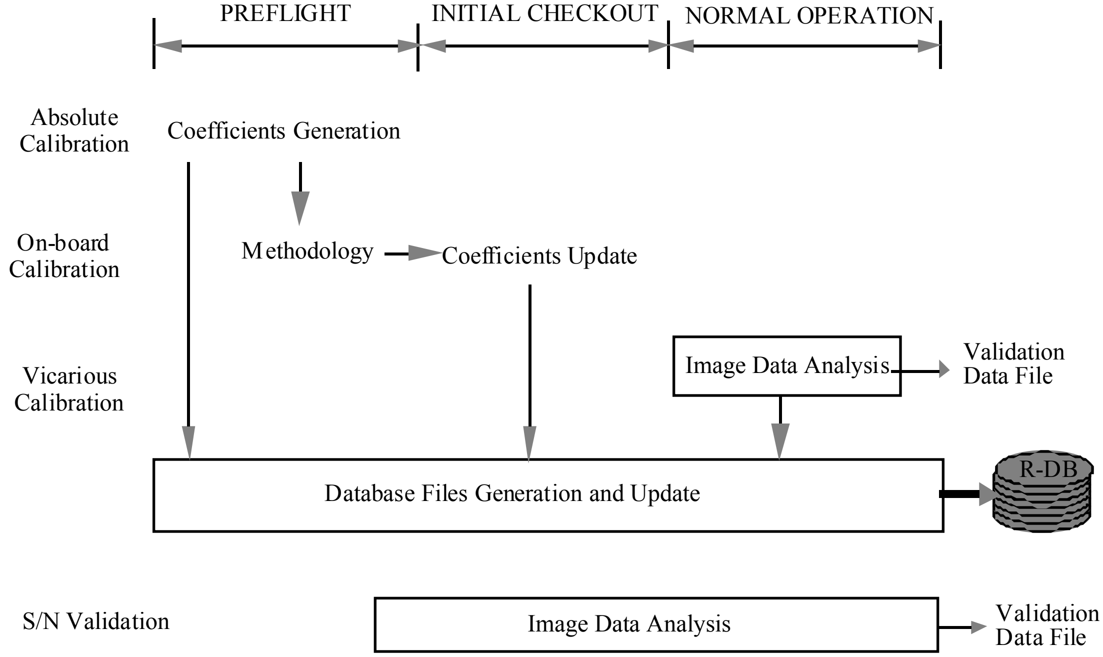

Figure 2. Radiometric Validation Activity

4.2.2 Geometric Performance

During the preflight test the line of sight (LOS) vectors will be evaluated toward the boresight coordinate frame of each telescope by using the collimator. Then during the integration and test on the spacecraft the nadir boresight coordinates (the boresight coordinates for the nadir position of the cross-track pointing) for each telescope is aligned to the Spacecraft Reference Axes (Navigation Base Reference) as exactly as possible. A small alignment error between each telescope and the spacecraft can be evaluated by using the instrument cube of each subsystem and the spacecraft cube. Thus the LOS vectors and the boresight vectors toward Navigation Base Reference (NBR) can be obtained with the coordinate transformation by an alignment error between two coordinate system. The final product during the preflight test is the preliminary geometric data base (Version 0) which contains a set of the LOS vectors toward the NBR. The cross-track pointing axis which is expressed toward the NBR is also a part of the geometric data base contents.

During the initial checkout period a fine tune-up process based on acquired image data will be carried out for the preparation of the geometric database with an accuracy for the operational use. The intra-telescope and the inter-telescope registration correction will be carried out for all bands relative to the reference band. The image matching techniques will be used for the error detection relative to the reference band 2. The geolocation error detection (absolute accuracy for LOS vectors) will be carried out only for band 2 using GCPs as references. The special GCP file is planned to be prepared for this geolocation error detection. A major purpose of this correction process during the initial checkout period is to evaluate a static pointing error as a whole including the spacecraft and the instrument.

During the normal operation period the inter-telescope band-to-band registration is to be carried out routinely in the Level-1 processing by the image matching to compensate a dynamic part of the pointing stability. The additional verification activity is planned to be carried out using the image matching techniques for the band-to-band registration and GCPs for the geolocation. Judgment will be done for the data base update if an average pointing error during TBD operation period (tentatively 3 months) exceeds some threshold value.

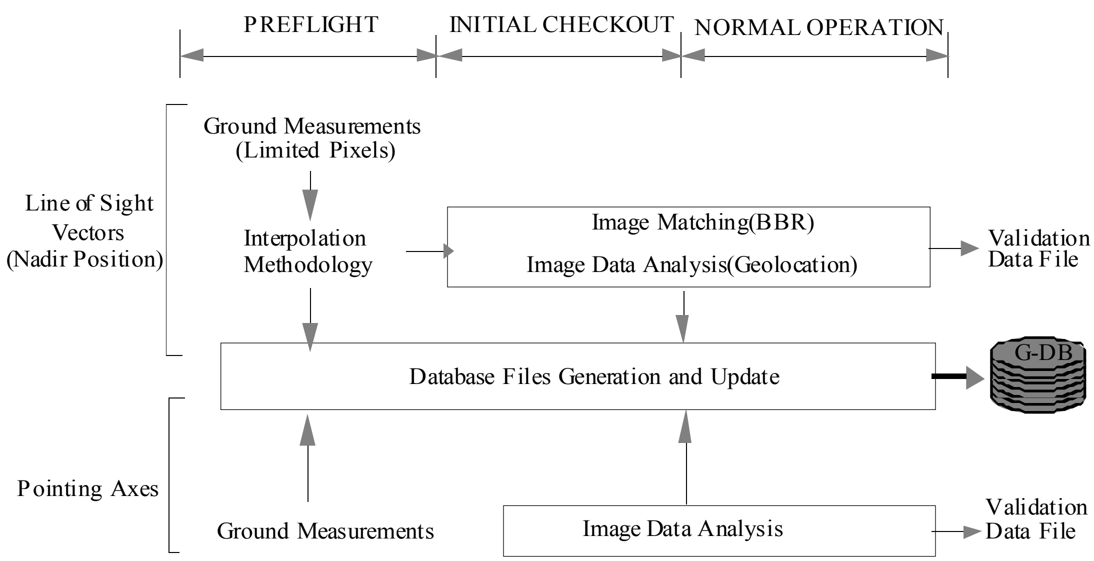

Figure 3 Geometric Validation Activity

4.2.3 MTF and Spectral Performances

The MTF and the spectral performances will be evaluated during the preflight test using a slit target and a spectrometer, respectively. In flight period the MTF will be validated with an edge response using acquired images. Regarding the spectral performance the spectral band confirmation will be carried out during the initial checkout period using acquired images with a good spectral feature. The details are TBD.

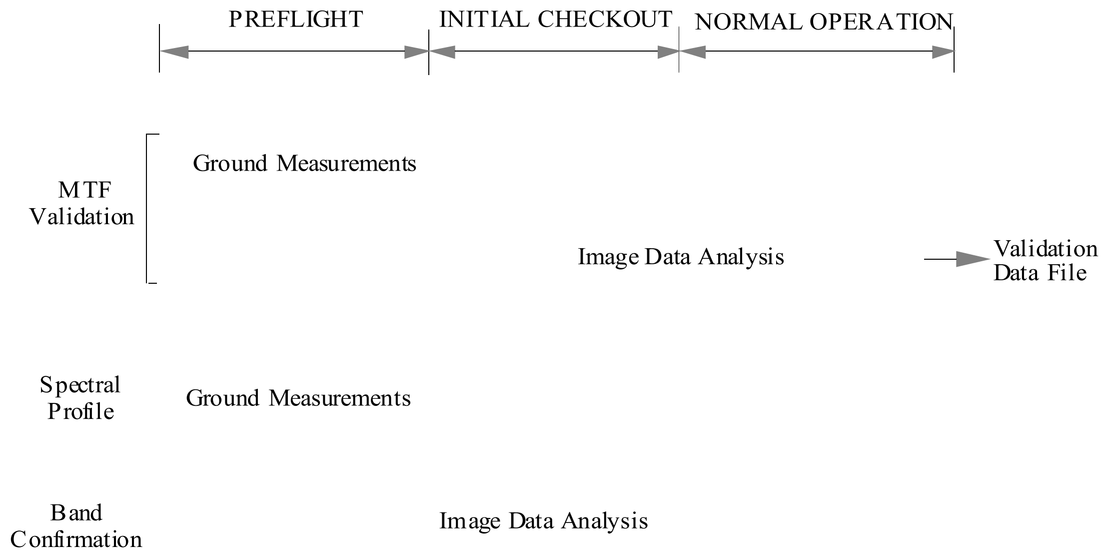

Figure 4 MTF/Spectral Performance Validation Activity

4.3 Required EOS and non-EOS Experimental Activities

Although there are no required EOS and Non-EOS experimental activities, ASTER recommends that an international collaborative VC program be established for EOS sensors. This should include non-EOS sensors where possible. This international VC program should be coordinated by the EOS Calibration Scientist through CEOS and/or by direct contact with other space agencies. It should thereby provide more frequent and appropriately spaced calibration up-dates than could otherwise be achieved. In addition an EOS calibration Panel sub-group should be to coordinate and oversee all EOS-related VC activities.

4.4 Required Operational Measurements

There are no special requirements for data acquisitions of the validation sites that coincide with the VC campaigns. However, because ASTER is a limited duty cycle sensor, it will be necessary to program the sensor to acquire data of the validation target. The only special requirement is that ASTER acquires data at the appropriate Lunar phase (calibration maneuvers are still under discussion).

A variety of ground-based measurements are required for the reflectance- and radiance-based methods and sensor-to-sensor comparison methods, which were outlined in Section 4.0.

4.4 Archival Plans for Validation Information

All vicarious calibration/validation field measurement data to be archived at the Oak Ridge National Laboratory, which is the designated DAAC for field data and, in some cases, related aircraft data. As a first step in this direction, the field data collected during the first VC joint field campaign in June 1996, are being archived at Oak Ridge.

5.0 Decorrelation Stretch (AST06)

5.1 Approach for Establishing Scientific Validity

The definition of "validation" adopted by the EOS Panel on Data Quality is that: "[Validation] involves specification of the transformations required to extract estimates of high-level geophysical quantities from calibrated basic instrument measurables and specification of the uncertainties in the high-level geophysical quantities." The decorrelation stretch is a visualization tool, one to make spectral differences within a scene more apparent to the observer. The result of the decorrelation stretch is not a geophysical quantity, nor is it quantitatively tied to any geophysical quantity. Validation, in the quantitative, geophysical sense as narrowly defined above, is not applicable. Validation for this product will be limited to testing the software for adherence to the algorithm specified in the theoretical basis document, examining the output data for inter-channel correlation, and visually examining the output for enhanced spectral contrast.

5.2 How will Accuracy, Precision, and Resolution be confirmed?

The statistical attributes of the output product (channel means and variances, and interchannel correlation) shall be examined as a test of correct implementation of the algorithm. Since this algorithm does no spatial resampling, the geometric accuracy, precision, and resolution are inherited from the Level-1 input.

5.3 Required EOS and non-EOS Experimental Activities

None required

5.4 Required Operational Measurements

None required

5.5 Archival Plans for Validation Information

None planned.

6.0 Brightness Temperature at Sensor (AST04)

6.1 Approach for Establishing Scientific Validity

The brightness temperature product is at its core a conversion from radiance to temperature units. For a given wavelength, this relationship is explicitly defined by the Planck function. For an ASTER thermal infrared channel, the Planck function must be convolved over the normalized spectral response function for that channel. The success criterion lies solely in the testing that the software uses the Planck function and the spectral response functions properly to calculate the conversion for radiance to temperature (as verified by independent external calculations). Once the uncertainties of the Level-1B product and spectral response function are determined, the uncertainty of this product may be calculated directly.

6.2 How will Accuracy, Precision, and Resolution be confirmed?

Assuming that the spectral response function is known, the computation of blackbody (brightness) temperature can be evaluated to be within any practical precision limit, certainly well within the limits of the precision of the input radiance data. Since the dominant sources of imprecision and error are the uncertainty of the input radiance data (Level 1B product) and the uncertainty of the spectral response functions (which are themselves tied to the validation of the Level 1B product), validation of this product is "piggy-backed" to the validation of the Level 1B, radiance at sensor product.

6.3 Required EOS and non-EOS Experimental Activities

It should be noted that the quantity being reported by this product is "at sensor", not "at surface". As such, strict agreement with ground measurements is not an issue, and field experiments are not envisioned.

6.4 Required Operational Measurements

None required.

6.5 Archival Plans for Validation Information

None planned.

7.0 Surface radiance - VNIR, SWIR (AST09)

7.1 Approach for Establishing Scientific Validity

Computer modeling using radiative transfer codes
In-situ validation

7.2 How will Accuracy, Precision, and Resolution be confirmed?

Two basic approaches are planned for this validation work: computer simulations and field campaigns.
The computer simulations will consist of radiative transfer modeling using computer codes to determine the retrieval's sensitivity to input parameter uncertainties. These radiative transfer code simulations will also be used to help determine what targets will be selected for in-situ validation work. This modeling work will be coupled with the field campaign results to reduce the amount of in-situ measurements needed. It would be difficult from a cost and personnel standpoint to fully sample all possible permutations of conditions expected for the surface reflectance retrieval. Thus, the current plan is to use in-situ measurements, described below, to validate the algorithm for several representative cases. Once the accuracy and precision of the algorithm has been shown to match predicted uncertainties, the computer codes used in the algorithm will be used to determine precision and accuracy's for other cases.

The field campaigns use in-situ measurements of surface properties of and atmospheric properties above a selected target. These measurements are made in conjunction with an overpass of the target by ASTER, or another suitable sensor. We will use these targets to test both the accuracy and precision of the final products as well as the sensitivity to the input parameters. The surface measurements will consist of transporting a calibrated radiometer across the target area and measuring the upwelling surface radiance. These measurements will be compared directly to the retrieved the surface radiance from the atmospheric correction algorithm. The radiances will be converted to surface reflectance by ratioing to radiances measured from a panel of known reflectance. These surface reflectances will also be directly compared to the retrieved values to determine the algorithm's accuracy. Precision of the retrieval will be determined by making measurements of the target corresponding to several pixels in the imagery and comparing the results in a relative manner. In addition to directly comparing the algorithm's output to measured surface values, we will use ground-based measurements of atmospheric parameters to evaluate the uncertainties caused by uncertainties in the input parameters.

7.3 Required EOS and non-EOS Experimental Activities

An opportunity exists for the above-described in-situ work to be done in conjunction with other field campaigns planned for the vicarious calibration of MODIS and ASTER. Unfortunately, these campaigns will supply only a small sampling of the types of targets required to fully understand this problem. Thus, field campaigns dedicated to the validation of this product will be required. Whenever possible, we will use field campaigns of opportunity to supplement our data sets. Any field campaign where surface radiance or reflectance data are collected over areas larger than 50 m by 50 m can be used. In addition, atmospheric extinction measurements at the time of sensor overpass are also desirable.

7.4 Required Operational Measurements

Operational measurements which are needed to directly determine the algorithm's accuracy are those normally required for the standard processing of this algorithm. This includes atmospheric aerosol information from MODIS and MISR processing, columnar gas amounts from MODIS or global assimilation models, and DEM inputs. Validation can still be done using the ground-based, in-situ atmospheric measurements, but this only allows us to validate the product and not to understand the effects of input uncertainties.

7.5 Archival Plans for Validation Information

All field campaign results will be available via a worldwide website. This site is currently being constructed with the results of a recent joint-field campaign for vicarious calibration. All data will also be archived to tape and will be made available to other users via ftp access when requested.

8.0 Surface Radiance - TIR (AST09)

8.1 Approach for Establishing Scientific Validity

a) *In situ* measurements by algorithm developers
b) Cross comparison with equivalent MODIS channels
c) Using *In situ measurements* from non-ASTER investigators

8.2 How will Accuracy, Precision, and Resolution be confirmed?

In situ Validation Method:

Radiometric measurements from a boat are used to estimate the kinetic temperature of the radiating surface of water areas the size of several ASTER TIR pixels.

An array of continuously recording buoys is used to assist in estimating the space and time variation in water temperature. To reduce geolocation error, 3X3 pixel areas will be instrumented.

Radiosonde profile measurements are used to determine the atmospheric temperature and moisture profiles for use with the radiation model MODTRAN to estimate the spectral sky irradiance.

The ASTER spectral response along with the surface kinetic temperature, the spectral emissivity of water and the spectral sky irradiance are used to compute the channel by channel surface leaving spectral radiance which is to be compared with the same quantity from the algorithm being validated.

Lake Tahoe and the Salton Sea are being evaluated as sites which provide a range of atmospheric conditions (e.g. warm-wet, warm-dry, cold-wet, cold-dry).

MODIS/ASTER comparisons:

ASTER and MODIS have similar channels between 10.78 and 11.65 µm. For targets of known spectral emissivity (e.g. water) comparison of the surface kinetic temperature across a wide range of atmospheric conditions provides a useful consistency check. Such comparisons can be conducted whenever ASTER data is collected over a suitable target as MODIS will provide continuous collection.

Using *in situ* measurements from non-ASTER investigators:

Both the MODIS land and oceans groups will be collecting data of the type suitable for use in the validation of the ASTER TIR atmospheric correction algorithm. We expect to cooperate with both groups in a two way exchange of data. Since ASTER is to be operated with an 8% duty cycle, planning will be required to collect ASTER data over sites where and when *in situ measurements* are being conducted.

8.3 Required EOS and non-EOS Experimental Activities

None

8.4 Required Operational Measurements

None required.

8.5 Archival Plans for Validation Information

Validation data and a description of the processes, procedures and algorithms used will be archived in the ASTER Team Leader Processing Facility.

9.0 Surface Kinetic Temperature (AST08) and Surface Emissivity (AST05)

9.1 Approach for Establishing Scientific Validity

a) Laboratory Modeling.
b) In-situ Validation.

9.2 How will Accuracy, Precision and Resolution be confirmed?

The accuracy and precision of the surface temperature and surface emissivity images will be confirmed using laboratory modeling and in-situ validation. In the laboratory modeling the emissivity spectrum of a known material is converted to radiance at a specified temperature and the radiance spectrum propagated through an atmosphere to produce an ASTER radiance at sensor spectrum. The emissivity and temperature of this spectrum are then recovered using the appropriate ASTER algorithms. A wide variety of materials are being examined as well as different atmospheres, possible instrument artifacts, and errors in the atmospheric input variables. The initial emissivity spectra are derived through laboratory and field measurement. This has necessitated the development of specialized field equipment.

In addition to the laboratory modeling there will also be a limited amount of in-situ validation. This involves going to a homogenous site and measuring the surface temperature and emissivity in-situ as well as characterizing the atmosphere. The surface temperature and emissivity will then be recovered from the ASTER data and compared with the measured values. The ASTER algorithms will utilize the atmospheric information that would normally be available in the ASTER time-frame as well as the additional
in-situ information to determine whether errors were due to inappropriate atmospheric input variables. This same approach will be used prior to launch using aircraft data as a surrogate for ASTER data.

9.3 EOS and non-EOS Experimental Activities

A set of validation test sites has been selected for the temperature and emissivity products. Information on these sites can be accessed through the EOS validation homepage. There is a commitment by the temperature-emissivity separation group to conduct experiments at these sites. In addition, whenever possible, the temperature-emissivity group will take advantage of any ad-hoc EOS and non-EOS experiments where useful validation information may be obtained.

9.4 Required Operational Measurements

The algorithm for extraction of temperature and emissivity does not require any operational measurements per se.

9.5 Archival Plans for Validation Information

Currently the archival plans for the validation information acquired post-launch are not established. Activity is underway to archive any pre-launch information. For example a have established an ASTER spectral library web site. The library contains visible through thermal infrared spectra of a wide variety of materials. These data have been utilized for the laboratory modeling. This system is backed up on a regular basis. Further sites may be established which contain the information acquired from pre-launch in-situ validation experiments.

10.0 Polar Surface and Cloud Classification (AST13)

10.1 Approach for establishing Scientific Validity

a) Testing of classification algorithm on sets of labeled samples.

Labeled samples are extracted by a human expert trained in identifying homogeneous pixel regions for classes of interest. Prelaunch, the labeled samples are extracted from Landsat TM data, primarily, but also from TIMS, AVIRIS, and MAS data. Postlaunch the samples will be extracted from ASTER data. The algorithm is applied to these samples and the classification result is recorded and compared to the actual class of the sample. This testing is currently being performed on approximately 200,000 samples. It provides confusion matrices depicting the percent classification accuracy for each class. This will be the primary method for establishing the classification accuracy of the algorithm.

b) Subjective analysis of color-coded classification masks.

Human experts examine color-coded masks of classification results and identify problem areas. These experts provide subjective estimates of accuracies/inaccuracies, primarily for clear vs. cloud.

c) Testing of classification algorithm on randomly selected samples.

Sample regions are selected at random (by the computer) for classification by a human expert. The human expert indicates the dominant class in the region. This is then compared to the predominant class indicated by the classification mask. These results also are accumulated in confusion matrices, similar to 1a).

d) Comparison of classification results with surface based observations.

When satellite overpasses and surface observations are coincident, measurements of cloud cover, cloud fraction, and cloud base height will be compared to the classification mask to determine if the algorithm correctly detected the presence of cloudiness. These types of comparisons are few in prelaunch due to the time and place of coverages available from Landsat TM data in the circumpolar regions. In postlaunch, the large volume of circumpolar ASTER data should provide for many coincident surface and overpass opportunities.

10.2 How will Accuracy, Precision, and Resolution will be confirmed?

Accuracy and validity for this product are synonymous and the methodology for confirming validity is described in 10.1. This product provides for a coded classification mask as opposed to an estimate of a physical quantity; therefore, precision is not germane. This product assumes that the resolution of the radiance measurements from the 3 telescopes (VNIR, SWIR, and TIR) are 15 m, 30 m, and 90 m, respectively. The daytime and nighttime products will be provided at 30 m and 90 m, respectively.

10.3 Required EOS and non-EOS experimental activities

The philosophy used in this algorithm development has been to take advantage of any affordable data sets that can serve as surrogates for ASTER data. Currently Landsat TM data provides the best match for ASTER data (although significantly different) with respect to band coverage, and spatial and spectral resolution. It also provides for the best aerial and temporal coverage of the polar regions. No specific experiments are planned beyond using the data obtained from experiments such as SHEBA. Additional experimental activities in circumpolar regions are needed.

10.4 Required Operational Measurements

As indicated in 10.1d), measurements of cloud cover, cloud fraction, and cloud base height are needed, for as many satellite overpasses as possible, to provide for a data independent assessment of the algorithm's ability to correctly detect the presence of cloud. These surface based measurements will come from NWS sites in the polar regions (such as Fairbanks and Anchorage, AK), DOE ARM sites in OK (wintertime) and AK, and ceilometer networks (limited to wintertime conditions at continental U.S. sites).

10.5 Archival Plans for Validation Information

An anonymous ftp site will be maintained at the South Dakota School of Mines and Technology on cloud.ias.sdsmt.edu in the directory pub/outgoing/aster. Files of confusion matrices (described in 10.1) will be maintained here. In addition, GIF files of 3-band overlays of the imagery used in the testing and validation of the algorithm will reside here as well as the color-coded classification masks.

11.0 Digital Elevation Models (AST14)

11.1 Approach for Establishing Scientific Validity

Because ASTER DEMs are geometry-based, direct, cartographic/geodetic measurements of the shape of the land surface their scientific validity is well established without any "scientific" validation. All relevant specifications are validated in 11.2) below.

11.2 How will Accuracy, Precision and Resolution be confirmed?

The overall approach is to confirm that ASTER-derived DEMs meet RMSExyz accuracy specifications by subtracting Z values from highly accurate DEMs, obtained from other sources, from Z values from ASTER-derived DEMs covering the same area, on a pixel-by-pixel basis. Precision and resolution do not require confirmation/validation because they are inherent properties of the data product resulting from the correlation/posting procedure used to produce the product.

11.3 Required EOS and non-EOS Experimental Activities

Twelve validation sites have been established. Highly accurate DEMs and ground control points are already in-hand for these sites. The only experimental activities required are yearly acquisition of cloud-free ASTER stereo data over each site throughout the mission, and implementation of the procedure described in 2) at the Land DAAC (EDC) ASTER DEM processing facility.

11.4 Required Operational Measurements

Yearly acquisition of cloud-free ASTER stereo data, annually over each of the 12 ASTER DEM validation sites.

11.5 Archival Plans for Validation Information

RMSExyz data for the 12 validation sites will be archived at the Land DAAC (EDC) ASTER DEM processing facility.